REMARKS

The Present Invention

The invention provides a semiconductor base comprising a substrate and a semiconductor crystal formed on the substrate by vapor phase growth. The semiconductor crystal is a GaN group semiconductor crystal defined by $Al_x Ga_{1-x-y} In_yN$, wherein $0 \leq x \leq 1$ and $0 \leq y \leq 1$. The substrate has a concavo-convex surface as a crystal growth plane, and the semiconductor crystal is grown exclusively from an upper part of a convex part of the concavo-convex surface. Such a semiconductor base has unique qualities over those in the prior art.

The crystal growth temperature of a GaN group semiconducter reaches at least 1000°C. There is no existing crystal substrate that does not evaporate or melt at such a high temperature, while still retaining a fine lattice constant for the GaN group semiconductor. Conventionally, sapphire substrates have been used for growing a GaN group semiconductor crystal, because sapphire substrates show high resistance to heat, though failing to lattice match therewith. Due to the mismatch in the lattice constant, a defect (e.g., a dislocation) occurs and a high quality GaN group semiconductor crystal cannot be obtained.

In order to solve this problem, the art describes the use of a mask in the growth method, wherein a base layer is partially masked to effect a selective crystal growth in a lateral direction. However, using this mask method with a GaN semiconductor crystal causes (a) cracks and breakage of substrate resulting from differences in lattice constant and in thermal expansion coefficient (failure to provide a substrate having a large area), (b) a slight tilt of the C axis toward the lateral growth direction in the part grown in the lateral direction on a mask layer (degradation of crystal quality), and (c) transfer of the Si component into the crystal growth layer due to lamination of a crystal growth layer on SiO_2 which is generally used as mask layer material (autodoping contamination). See present specification, page 1, line 27 – page 3, line 30

The semiconductor base of the present invention resolves the above-mentioned problems with the mask method by using a concavo-convex surface of the substrate as a crystal growth plane and growing the GaN group semiconductor crystal exclusively from an upper part of a convex part on the concavo-convex surface. The inventors have discovered that the dislocation density of GaN group semiconductor crystal can be reduced by crystal growth on a crystal substrate having a concavo-convex surface.

The Pending Claims

Claims 1 and 3-21 are pending.

The Amendments to the Claims

Claim 1 has been amended to point out more particularly and claim more distinctly the present invention. Specifically, claim 1 has been amended to incorporate the characteristics of claim 2. Accordingly, claim 2 has been cancelled to prevent redundancy. The amendment to claim 1 also is supported by the specification at, e.g., page 10, lines 10-14. No new matter has been added by way of these amendments. Separate documents setting forth the amendments to the claims, as well as the text of all of the pending claims as amended are enclosed.

The Office Action

The Office Action has rejected claims 1-10 under 35 U.S.C. § 103(a), as obvious in view of Vichr et al. (U.S. Patent No. 5,614,019) in combination with Kawasumi et al. (JP 10-178026), Shigeta et al. (U.S. Patent No. 5,729,701), Usui et al. (U.S. Patent No. 6,252,261), and/or Vaudo et al. (U.S. Patent No. 6,156,581). Claims 11-21 were not addressed in the Office Action because those claims are directed to non-elected subject matter in response to a restriction requirement. Reconsideration of the obviousness rejection is hereby requested.

Discussion of Obviousness Rejection

The Office has indicated that it would have been obvious for one of skill in the art to combine the selective growth, direction, and configurational structure of crystal growth as taught by Kawasumi et al., Shigeta et al., and Usui et al., respectively, with the crystal growing method of Vichr et al. in order to provide a semiconductor crystal growth with high controllability as recited in the pending claims (Office Action, pages 2-3).

According to the Office, Vichr et al. discloses a method for growing large, single crystals. The Office concedes that Vichr et al. does not teach the selective growth of crystals from the upper part of a convex part of a concavo-convex surface of the substrate or the specific directional growth configuration. Vichr et al. relates to the crystal growth of diamond, cubic boron nitride, and silicon carbide, and not a GaN crystal, as recited in the pending claims. Moreover, Vichr et al. does not describe the problems associated with a GaN group semiconductor and the inventive concept that the dislocation density of GaN group semiconductor crystal can be reduced by crystal growth on a crystal substrate having a concavo-convex surface.

The Office contends that Kawasumi et al. discloses a crystal growth method in which there is selective growth of crystals on the concave part of the substrate. Kawasumi et al. describes the crystal growth of group II-VI semiconductors with fine crystal substrates. Therefore, Kawasumi et al. does not face the problems of lattice mismatch that the present

invention sought to solve. Furthermore, as is clear from a comparison of Figure 6 of Kawasumi et al. and Figure 1 of the pending application, the crystal growth of Kawasumi et al. and that of the present invention are quite different from each other. In Kawasumi et al., the performance of a semiconductor laser is improved by improving the quality of the crystal layer. This is done by embedding a strip ridge (element 20a) in the substrate (see enclosed Patent Abstract of Japan corresponding to JP 10-178026), which is unlike the present invention. Similar to Vichr et al., Kawasumi et al. does not describe the problems associated with a GaN group semiconductor and the inventive concept that the dislocation density of GaN group semiconductor crystal can be reduced by crystal growth on a crystal substrate having a concavo-convex surface.

Shigeta et al. allegedly discloses a method of growing silicon carbide single crystals with the claimed directional structure. However, the specific property relating to the crystal direction is unique to each material and varies depending on the material. Therefore, the direction relating to the SiC single crystal that is described in Shigeta et al. does not correspond to the GaN group crystal of the present invention. Additionally, Shigeta et al. does not disclose concavo-convex surface processing of the substrate as required by the pending claims.

The Office contends that Usui et al. discloses a GaN crystal film, a Group (III) nitride semiconductor wafer, and a method of growing crystals with the claimed crystal configuration. Usui et al. discloses the use of the mask method for the crystal growth of GaN. As described above, the use of the mask method with a GaN semiconductor crystal causes (a) cracks and breakage of substrate resulting from differences in lattice constant and in thermal expansion coefficient (failure to provide a substrate having a large area), (b) a slight tilt of the C axis toward the lateral growth direction in the part grown in the lateral direction on a mask layer (degradation of crystal quality), and (c) transfer of the Si component into the crystal growth layer due to lamination of a crystal growth layer on SiO_2 which is generally used as mask layer material (autodoping contamination). Usui et al. does not acknowledge such problems, does not provide the motivation to solve such problems, and does not disclose the constitution of the semiconductor crystal necessary to solve such problems. As described above, the semiconductor base of the present invention resolves the above-mentioned problems with the mask method by using a concavo-convex surface of the substrate as a crystal growth plane and growing the GaN group semiconductor crystal exclusively from an upper part of a convex part on the concavo-convex surface, which is not contemplated by Usui et al.

Vaudo et al. discloses a GaN-based device containing a (Ga, Al, In)nitride base layer. Vaudo et al., however, does not disclose or suggest concavo-convex surface processing of the substrate as recited in the pending claims.

Accordingly, Vichr et al., Kawasumi et al., Shigeta et al., Usui et al., and Vaudo et al. do not teach or suggest all the features of the claims of the present invention, even when considered collectively, and do not suggest the combination and modification of their respective disclosures in the manner necessary to arrive at the semiconductor base of the present invention. Under the circumstances, the obviousness rejection of the pending claims should be withdrawn.

Conclusion

The application is considered in good and proper form for allowance, and the Examiner is respectfully requested to pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of the subject application, the Examiner is invited to call the undersigned attorney.

Respectfully submitted,

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Date: February 20, 2003

CERTIFICATE OF MAILING

I hereby certify that this RESPONSE TO OFFICE ACTION (along with any documents referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, Washington, D.C. 20231.

Date: February 20, 2003

PATENT
Attorney Docket No. 213578
Client Reference No. 20836

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Tadatomo et al.

Art Unit: 2826

Application No. 09/936,683

Examiner: F. Erdem

Filed: November 30, 2001

For: SEMICONDUCTOR BASE AND ITS MANUFACTURING METHOD, AND SEMICONDUCTOR CRYSTAL MANUFACTURING METHOD

AMENDMENTS TO CLAIMS
MADE IN RESPONSE TO OFFICE ACTION DATED NOVEMBER 20, 2002

Amendments to existing claims:

1. (Amended) A semiconductor base comprising a substrate and a semiconductor crystal formed on said substrate by vapor phase growth, wherein (a) the semiconductor crystal is a GaN group semiconductor crystal defined by $Al_x Ga_{1-x-y} In_y N$ where $0 \leq x \leq 1$ and $0 \leq y \leq 1$, (b) the substrate has a concavo-convex surface as a crystal growth plane, and (c) the semiconductor crystal is grown exclusively from an upper part of a convex part of the concavo-convex surface.

2 (Cancelled)

PATENT
Attorney Docket No. 213578
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Application No. 09/936,683

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Examiner: F. Erdem

Filed: November 30, 2001

For: SEMICONDUCTOR BASE AND ITS MANUFACTURING METHOD, AND SEMICONDUCTOR CRYSTAL MANUFACTURING METHOD

PENDING CLAIMS AFTER AMENDMENTS MADE IN RESPONSE TO OFFICE ACTION DATED NOVEMBER 20, 2002

1. A semiconductor base comprising a substrate and a semiconductor crystal formed on said substrate by vapor phase growth, wherein (a) the semiconductor crystal is a GaN group semiconductor crystal defined by $Al_x Ga_{1-x-y} In_yN$ where $0 \leq x \leq 1$ and $0 \leq y \leq 1$, (b) the substrate has a concavo-convex surface as a crystal growth plane, and (c) the semiconductor crystal is grown exclusively from an upper part of a convex part of the concavo-convex surface.

3. The semiconductor base of claim 1, wherein the convex parts of the crystal growth plane of the substrate form parallel stripes.

4. The semiconductor base of claim 3, wherein the semiconductor crystal is InGaAlN and a longitudinal direction of the stripe is in parallel to a (1-100) plane of the InGaAlN crystal.

5. The semiconductor base of claim 1, which comprises the substrate and the semiconductor crystal formed on said substrate by vapor phase growth, wherein the substrate has the concavo-convex surface as the crystal growth plane, the semiconductor crystal is grown exclusively from the upper part of the convex part of the concavo-convex surface, the concavo-convex surface is covered with a semiconductor crystal grown, and a cavity is formed between the semiconductor crystal layer and the concave part of the concavo-convex surface.

6. The semiconductor base of claim 1, wherein the concave part of the concavo-convex surface of the substrate is covered with a mask on which the crystal cannot substantially grow, and the semiconductor crystal is crystal grown exclusively from the upper part of the convex part of the concavo-convex surface of the substrate.

7. A semiconductor base comprising a first semiconductor crystal layer obtained by making a crystal growth plane of a substrate a concavo-convex surface and crystal growing exclusively from an upper part of a convex part of the concavo-convex surface by vapor phase crystal growth, and a second semiconductor crystal layer formed by making a surface of the first semiconductor crystal layer a concavo-convex surface and similarly crystal growing exclusively from an upper part of the convex part of the concavo-convex surface.

8. The semiconductor base of claim 7, wherein the concave part of the concavo-convex surface of the substrate is covered with a mask on which the crystal cannot substantially grow, the first semiconductor crystal layer is formed by crystal growth exclusively from the upper part of the convex part of the concavo-convex surface of the substrate, the convex part of the concavo-convex surface of the first semiconductor crystal layer is covered with a mask, on which the crystal cannot substantially grow, and the second semiconductor crystal layer is formed by crystal growth exclusively from the upper part of the convex part of the concavo-convex surface of the first semiconductor crystal layer.

9. A semiconductor base comprising a third semiconductor crystal layer formed by making a surface of the second semiconductor crystal layer of the semiconductor base of claim 7 a concavo-convex surface, and similarly vapor phase growing thereon, or plural semiconductor crystal layers formed in multiplicity by repeating similar steps.

10. A semiconductor base comprising a third semiconductor crystal layer formed by making a surface of the second semiconductor crystal layer of the semiconductor base of claim 8 a concavo-convex surface, covering the concave part with a mask on which the crystal cannot substantially grow, and similarly vapor phase growing thereon, or plural semiconductor crystal layers formed in multiplicity by repeating similar steps.

11. A method for manufacturing a semiconductor base, which method comprises, for vapor phase growth of a semiconductor crystal on a substrate, processing the substrate

surface in advance to give a concavo-convex surface, supplying an ingredient gas to the substrate, and covering the concavo-convex surface of the substrate with a semiconductor crystal formed by crystal growth exclusively from an upper part of a convex part of the concavo-convex surface.

12. The method of claim 11, wherein the concave part of the concavo-convex surface of the substrate is covered with a mask on which the crystal cannot substantially grow, and an ingredient gas is supplied to the substrate, whereby the concavo-convex surface of the substrate is covered with a semiconductor crystal grown exclusively from the upper part of the convex part of the concavo-convex surface.

13. A method for manufacturing a semiconductor crystal, which method comprises making a crystal growth plane of a substrate a concavo-convex surface, growing a crystal exclusively from an upper part of a convex part of the concavo-convex surface by vapor phase growth to cover the concavo-convex surface with a semiconductor crystal, thereby giving a laminate comprising a cavity between the semiconductor crystal layer and the concave part of the concavo-convex surface, and separating the semiconductor crystal from the substrate at said cavity part.

14. The method of claim 13, wherein the concave part of the concavo-convex surface of the substrate is covered with a mask on which the crystal cannot substantially grow, and thereafter the crystal is grown by vapor phase growth exclusively from the upper part of the convex part of the concavo-convex surface.

15. The method of claim 13, wherein the semiconductor crystal is InGaAlN.

16. The method of claim 13, wherein the convex parts of the crystal growth plane of the substrate form parallel stripes.

17. The method of claim 16, wherein the semiconductor crystal is InGaAlN and a longitudinal direction of the stripe is perpendicular to a (1-100) plane of the InGaAlN.

18. A method for manufacturing a semiconductor crystal, which method comprises making a crystal growth plane a concavo-convex surface, growing a crystal exclusively from an upper part of a convex part of the concavo-convex surface by vapor phase growth to cover the concavo-convex surface to form a first semiconductor crystal layer,

making a surface of the first semiconductor crystal layer a concavo-convex surface, growing a crystal exclusively from an upper part of a convex part of the concavo-convex surface of the first semiconductor crystal layer to cover the concavo-convex surface with a second semiconductor crystal layer, thereby giving a laminate comprising a cavity between the second semiconductor crystal layer and the concave part of the concavo-convex surface, and separating the semiconductor crystal from the substrate at said cavity part.

19. The method of claim 18, wherein the concave part of the concavo-convex surface of the first semiconductor crystal layer is covered with a mask on which the crystal cannot substantially grow, and thereafter, the second semiconductor crystal layer is crystal grown by vapor phase growth exclusively from the upper part of the convex part of the concavo-convex surface.

20. A method for manufacturing a semiconductor crystal, which method comprises making a surface of the second semiconductor crystal layer in the manufacturing method of claim 18 a concavo-convex surface, forming a third semiconductor crystal layer by vapor phase growth, or plural semiconductor crystal layers in multiplicity by repeating similar steps, thereby giving a laminate comprising a cavity between the semiconductor crystal layer and the concave part of the concavo-convex surface, and separating the semiconductor crystal from the laminate at the cavity part.

21. A method for manufacturing a semiconductor crystal, which method comprises making a surface of the second semiconductor crystal layer in the manufacturing method of claim 19 a concavo-convex surface, covering the concave part of the concavo-convex surface with a mask on which the crystal cannot substantially grow, forming a third semiconductor crystal layer by vapor phase growth, or plural semiconductor crystal layers in multiplicity by repeating similar steps, thereby giving a laminate comprising a cavity between the semiconductor crystal layer and the concave part of the concavo-convex surface, and separating the semiconductor crystal from the laminate at the cavity part.

PATENT ABSTRACTS OF JAPAN

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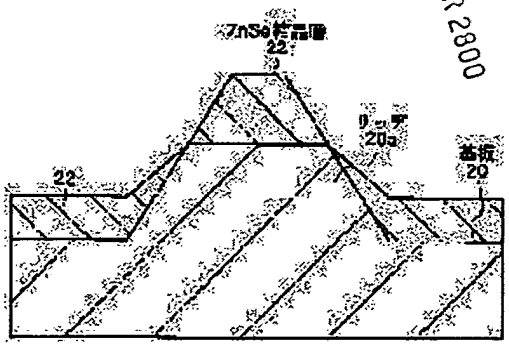
(54) CRYSTAL GROWTH METHOD AND METHOD FOR MANUFACTURING SEMICONDUCTOR LUMINESCENT ELEMENT UTILIZING THE SAME

(57)Abstract:

PROBLEM TO BE SOLVED: To selectively grow a crystal layer of a II-VI compound semiconductor on a substrate having a concave or convex part, and enhance crystallinity of a crystal layer.

SOLUTION: A stripe ridge 20a is formed in a quasi-mesa direction in a substrate 20 of (100) face. Respective particle beams of zinc of a group II element and selenium of a group VI element are irradiated onto this substrate 20 to grow a ZnSe crystal layer 22. ZnSe is used as a material of the respective particle beams to fill K cells. A cell temperature is 300°C or more. A growing temperature is 340°C by heating the substrate 20. Thereby, a growing speed on (111) A face is much slower than the (100) face, and the ZnSe crystal layer 22 is selectively grown in the (100) face. This ZnSe crystal layer has excellent crystallinity even near an inclined face.



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